BUS PRIORITY EFFECTS IN URBAN MOBILITY
Case Study: Application of a microscopic simulation model to study an artery in Cordoba, Argentina.

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ABSTRACT

Public transport is clearly an efficient means of transport. It responds to mobility demand, contributes with the environment generating less pollution and also preserves energy resources. In spite of this, in Cordoba city its use has continuously been reduced in the past few years.

Speed is one of the factors affecting the system operation. Time optimization benefits users, lowering their total travel times, as well as operators, optimizing size fleets to respond to demand.

Bus lanes or streets left only for bus use are one of the solutions implemented as a policy in central business districts where frictions between passenger cars and buses is significant.

The scope of this paper is to analyse the effects of bus lane use in bus circulation speeds and their role in the instauration of a sustainable urban mobility. To achieve this goal, two sections of an artery were modelled by NETSIM, a microscopic simulation model. One of them with mixed traffic and the other with bus lanes. Speed measures from year 2000 and 2005 were collected, comparisons between both situations were made and conclusions extracted.

The results obtained show the importance of comprehensive circulation management policies in favour of urban public transport. Not always the implementation of another bus lane results in a better solution. In fact, measures like bus priority lanes and right turn prohibitions can offer an increase in bus speeds of approximately 25%.

FIRST PART

1. STUDY CONTEXT

1.1. Cordoba: a particular urban space.

Argentina is one of the countries worldwide where death caused by traffic accidents in urban locations is continuously increasing.

Multiple reasons lead to this, but one of the basic causes is the lack of respect for and obedience of traffic law, and poor efficiency in transport system operation.

Obviously, Cordoba city does not escape from such situation.

Cordoba city, capital of the province of the same name, occupies 576 km2 and its population is approximately of 1.300.000 according to the 2001 population census, and it is considered to be the second largest city in the country, after Buenos Aires and followed closely by Rosario.

The city was founded on the banks of the Primero river, also known as Suquia river, in 1573, by the colonist current from Peru. It is located in the central region of Argentina. From its foundation the city was organized in accordance with its attributed functions: the administration of the new territories and economic centre of the internal market of the colonies.

In 1766 the Jesuits founded the Cordoba University. Cordoba was selected for its strategic situation. The Jesuit's authority politic centres from that time were from Paraguay, Tucuman and Chile. Added to the prestige of its university, Cordoba concentrates a great number of intellectuals, students and professionals giving the city a University town characteristic.

In conclusion, a communication strategic pole, transformed later in a cultural, commercial and production centre will permit its integration in the country and its insertion in the new century with a rapid future development characterized by a demographic and industrial growth confirming that way its "urban destiny".

If the most visible city transformations are related to the demographic increase, the most hidden are the product of complications in its social structure and population's different accessibility to the urban space.

The city developed on both sides of the river, dividing the areas with higher population density (downtown area) characterized by a large mix of functions (residential, commercial, educational, administration), from other areas, mainly residential ones, with one-family homes.

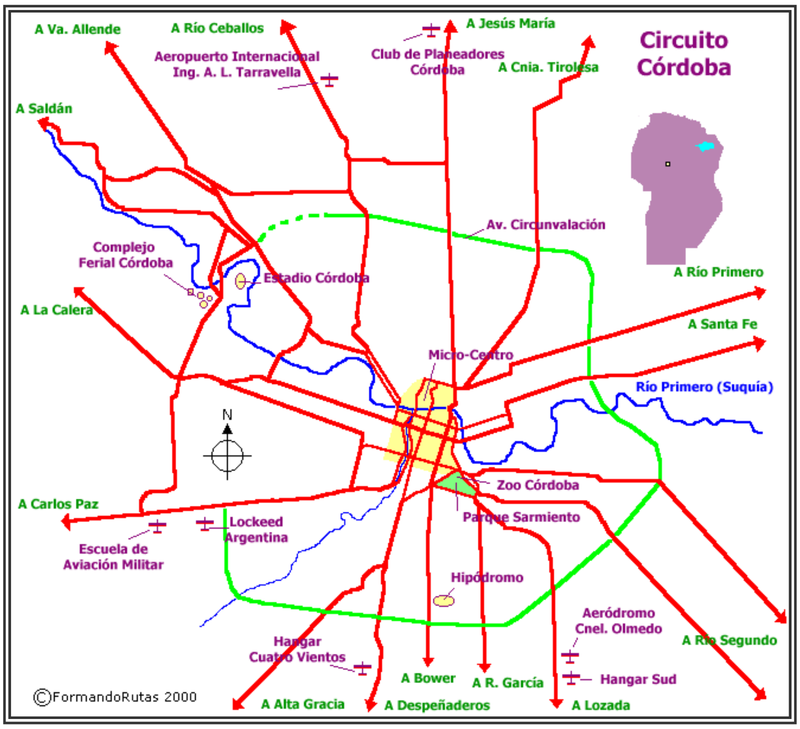


Figure 1. Situation plan of Cordoba city.

1.2. Mixed functions and transport concentration flows

The great city concentrated functions made it a magnetic pole with big attraction to the rest of the metropolitan area, generating in consequence significant daily flow rates. This is the cause of numerous problems in the domain of urban transport. Indeed, the motorization rate increases, the use of the passenger cars too, and the urban streets become jammed. Consequently, the public transport network has had to meet and absorb in comfortable conditions the increasing demand.

In our opinion, the existence of durable urban transport can not put aside the implementation of integral measures capable of decreasing the general circulation.

But before considering a specific measure, evaluation of the real incidence of this measure over all the transport modes involved in the artery studied is necessary.

It is well-known that mass public transport constitutes the most adequate means for the management of traffic flows, especially for central business district (CBD) destinations.

In the last past few years there has been a decrease in the use of public mass transport, due specifically to lack of investment in the sector, and consequently an important development of the alternative modes such as taxis and hire-cars.

Therefore, the Municipality has invested in the progressive recuperation of the mass public transport system; but at the same time, and contradictory, has doubled the number of licenses for taxis and hire-cars. This has produced an important increase in this sector in detriment of a rapid mass public transport growth.

1.3. Description of the public passenger transport system in Cordoba

The public transport system is constituted by:

- a network of mass transport constituted by buses and trolleys
- an individual transport system constituted by taxis and hire-cars

The bus network is organized with radial lines servicing the neighbourhoods and passing through the downtown centre. Two ring lines, one of them around the centre and the other one external, complete the network. Three operators, one of them the City Hall, manage the system. The different bus lines can be distinguished from each other by colour, depending on the operator that manages it and the area where they operate. In addition, in each area there are sub-lines that are identified by specific numbers.

The buses circulate mixed within all the traffic with some exception on arteries, where bus lanes exist.

Trolley buses circulate in the neighbourhoods on lanes where they have priority over buses. In the downtown area they use the lanes for public transport which they share with the other systems.

The City Hall authority regulates the system's transport fare (bus and trolley). The way that the bus or trolley fare is paid is with a token that the passenger can buy in small shops which are authorized by the City Hall to sell them o other small shops which only sell tokens. The system does not have a ticket person in the bus; therefore the bus driver is in charge of taking the passenger's token when they gets on the bus.

Taxis can operate in any city street, without restrictions, and they may use whenever they consider it necessary the privileges assigned for public transport. In the downtown area there are taxi ranks with clear signs where passengers can get off or on. Passengers can get a taxi in the streets or call one by phone.

The hire-cars are cars which passengers can call by phone exclusively. The hire-car's fare is just a bit more than the taxis one. They can also benefit from the privileges of public transport systems. This system has been in place since the 1990s and has been growing ever since, up to the point of doubling the number of cars circulating on the city streets of Cordoba.

The City Hall authority also regulates the individual transport fare (taxis and hire cars)

In the downtown area, buses generally circulate through arteries or through lanes assigned only to public transport, with traffic lights, in all intersections, included in the City Central Traffic Control System. In this system, public transport does not have priority

As said, bus lanes used for the circulation of public transport vehicles are shared with taxis and hire cars.

They are located on the right, following the only direction of circulation of the artery. In all cases, there are at least two lanes available, so that in this way the circulation of vehicles is not delayed by the loading or unloading of passengers.

The bus stops on the sidewalks have a density of 2 and 3 stops per km. Each stop has only one loading area, where various bus lines stop. This causes the buses to form long queues in peak hours, while waiting their turn to offer service at the stop.

SECOND PART

2. THE STUDY DEFINITIONS

2.1. The principal parameters studied

In public transport, speed is one of the key parameters that have got an effect on traffic when measuring efficiency in the city streets. An adequate management geared towards putting mass public transport as a priority benefits not only the users but also the operators. Users benefit because the time of their journey gets reduced, and the operators benefit because they will be able to improve the best use of the size of their fleet.

The objective of this study is to measure in the downtown area the impact of implemented measures on an artery bus lane speed and in consequence on volume during peak hours.

In effect, the City Hall increased in one the lanes for public transport. The question is to determine the impact of this lane in flow fluidity.

2.2. The sections studied

Colon Avenue is one of the most important avenues in Cordoba. It crosses the city from West to East passing through downtown centre. The section analyzed has an extension of 1,549 m. between Santa Fe Av. and General Paz Av. It crosses eleven intersections, all of them signalized except the third intersection after Santa Fe Av.

Three different sectors can clearly been defined.

The first of them, 544.5 meters long, with mixed traffic, where the vehicular composition is indicated in Table 1.

Table 1: Vehicular composition

Individual transport (in vph)			Mass transport (in uph)
Passenger cars	1036	74 %	90
Taxis/hire-cars	364	16 %	
Total	1400	100 %	

The second section, called the transition sector or section, with 287.5 meters of length.

And the third section where lanes assignment is the public transport (bus, trolley, taxis and hire cars) of 575.5 meters long. Despite its assignment, private passenger cars were observed, the majority authorized by the City Hall.

In this third section the total volume, public transport together with private passenger cars, reaches approximately 1700 vph., being the mass transport unites approximately of 160 uph.

There are bus stops in every block, except for the first and fourth one from the first section. Measured dwell times in the second and third blocks were of 35 seconds, and 50 seconds in the last four blocks of the third section.

The complete section presents 25 bus stops. Every stop is used by many lines totalizing 21 circuits. There is an important number of lines that enter the transition section making the mass transport units increase considerably.

2.3. Section modelling

It is well known that those simulation models permit the analysis of real situations. Particularly microscopic simulation models deal with individual vehicles path.

The NETSIM model was used in this case because:

- → it can deal with bus lines specifying routes, bus stops, dwell times and frequency,
- → it outputs separately bus measures from effectiveness.

The model outputs are presented:

- → by link: number of trips and total travel time (in minutes),
- → by stop: units served by the stop, reports the time the bus capacity is exceeded,
- → by line: average total time.

To calibrate a microscopic model a very large amount of information is required. Information about the transport operation system such as trajectories, stops, dwell times, bus frequency, bus performance characteristics, infrastructure, signalling, bus driver's performance, line operation speed, as the most relevant.

The data collection was made in morning peak hours (from 11:30 to 13:30) during weekdays.

THIRD PART

3. DATA AND RESULTS

3.1. Speed before and after.

At the end of 2000 the operational policy on the Colon Avenue in the city of Cordoba changed, it went from having two lanes assigned for public transport (for the exclusive use of buses, trolley buses, taxis and hire car) to having three (of a total of five available lanes).

Film records were available for the section of this avenue between Sucre and Tucuman streets (belonging to the third section), which were obtained by the Traffic Lights Intelligent Control Centre in the year 2000, when Colon street only had two selective lanes. This allowed us to measure bus speeds for that stretch of the street, in a situation that no longer exists today, as well as the vehicle volumes and composition for each lane.

For that stretch of the street, we measured in-situ, the speeds of the buses and the vehicle volume in the three selective lanes that are used today by the city public transport. These measurements were taken at the same time of the day as the one registered in the film records.

Given the fact that we wanted to study the effect of the extra selective lane on circulation, we didn’t compute the speeds of those vehicles that had stops in that stretch of the street.

From the film records, we obtained a speed of 16 km/h for an hourly vehicular volume of 821 mixed vehicles, with a percentage of participation of buses of approximately 13%, while the measurements on site where of 19 km/h for a vehicle flow of 1,200 vehicles with approximately 13% buses.

We must point out that in the first situation, the third lane, now being used exclusively for public transport vehicles (mass transport or individual) was assigned for private vehicles, but was occasionally being used by buses when they intended to overpass slower vehicles in the second selective lane.

The proportion of taxis that utilized the third lane changed with the new policy. Nowadays we observe a value of 30% for private vehicles while in the first situation that was the proportion of individual public transport (taxis and hire-cars).

The values for speed, total volumes, and bus volumes that we obtained for the first situation (or the before-case) and the second situations (or the after-case) are given in Table 2.

Table 2: Speed and volume data.

	Before (2000)	After (2005)
Selective lanes	2	3
Speed (km/h)	16	19
Mixed volume	821	1186
Bus volume	110	160

It should also be noted that the new city policy of granting a priority on public transport allowed an improvement of 20% in the speed of operation of the buses in the stretch under study, even when the vehicle flow increased 45% (as a consequence of the increase in the amount of registered vehicles and circulation along the third lane).

3.2. Modelling the transport system

The model includes six types of stops in accordance to the distributions of dwell times. Taking into account the average dwell times surveyed and their variance, a stop type was assigned to each of the 25 stops in the calibration process.

Stops from 1 to 19 belong to the selective lanes and the transition section. They work with an average dwell time of 50 seconds. Stops 20 to 25 from the mixed traffic section operate with a 35 second dwell time.

Seven places were selected from the total section of Colon Avenue to register vehicular path times:

- at the beginning and end of the first and last section,
- at the transition section,
- two measures in the selective lane section.

The data recollected revealed a speed of 10,40 km/h in accordance to previous studies in which the speeds obtained were approximately of 11 km/h.

The calibration required an important effort. The model was run with the data and outputs compared to the surveyed data. The model was adjusted to the real world. An average total travel time of 8.80 minutes (over 50 cases) was obtained from the surveys. The model output was 9.17 minutes for the entire section, 2.93 minutes for the mixed traffic section and 4.35 for the selective lane section. These values are in correspondence with those of 2.94 minutes and 4.35 minutes collected.

In order to test statistically its value, 16 simulation runs were generated with the present situation (as base case). The average total travel time was 9.08 minutes, 2.96 minutes and 3.98 minutes for the total section, the mixed traffic section and the selective lane section respectively.

The differences found were tested to determine if they were significant. A test of hypotheses between measured and simulated average travel times of the mixed traffic and selective lane sections was conducted.

Table 3 reports the results obtained. It can be seen that they are smaller than the critic ones, so the hypotheses can not be refuted and say, with a significance of 0.05, that the differences observed are not due to hazard. It can be concluded that the model is calibrated and ready for use.

Table 3: Test of hypotheses

Statistic	Mixed traffic	Selective lanes
T	0,125	0,16
T	2,002	1,984

With the calibrated model, different scenarios were modelled to reflect different politics.

Considering the present situation as Scenario 1, three hypotheses were tested to analyse the impact caused in bus speeds by different measures taken with respect to public transport.

Scenario 1: PRESENT SITUATION. Three selective lanes for public transport mass a well as individual.

Scenario 2: PROGNOSIS: two selective lanes. This hypothesis wants to reflect the impact if no measure had been taken in 2000.

Scenario 3: TWO EXCLUSIVE BUS LANES (circulation prohibited to individual public transport: taxis and hire-cars). This hypothesis wants to reflect the impact of preserving two lanes for public transport but no individual public transport.

Scenario 4: RIGHT TURNS PROHIBITED. This hypothesis wants to reflect the impact of a mass public transport policy.

The values for simulated times in the total section, transition and selective lane sections are given in Table 4.

Table 4: Section simulated bus travel times

Scenario	Total section (min)	Mixed traffic (min)	Transition (min)	Selective lanes (min)
1	9,17	2,93	1,89	4,35
2	14,65	3,22	4,42	7,02
3	7,49	2,69	1,94	2,86
4	8,55	3,14	2,10	3,31

It can be seen that if no measure had been taken (Scenario 2) nowadays the total travel time of the entire section would have been 60% greater, totalizing 14.65 minutes.

The bus flow rate would be of 110 uph (22% less) due to bus stop capacity and lane capacity that restrains demand.

In the blocks without stops of the mixed traffic section, bus speeds are practically the same. In the rest there is an increase of the travel times due essentially to friction effects between vehicles, which increases as the blocks reach the end of the section.

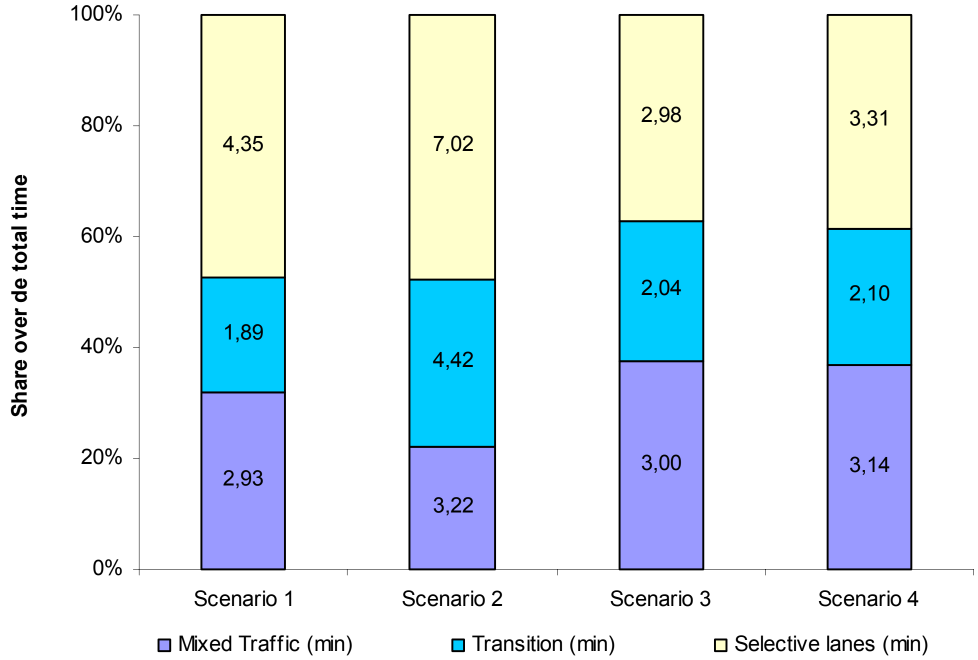
In the section without selective lanes the total travel bus time increased 10%.

In the transition section the same is observed. This indicates that the congestion produced upstream has an important effect downstream that is greater in the case of being close to it or if it lasts too long.

In the selective lane section the impact of the measure taken can be clearly seen: speeds reduction is of 60%.

Scenario 3 shows that maintaining two selective lanes, but only for bus use (bus lanes) would have derived in an increase of 12% in bus speeds section without consequences in the mixed traffic section and a bus speed improvement of 30% in the selective lane section. The flow rate also had an increase of 12% due to the increase in the lane capacity.

The prohibition of right turns by passenger cars (Scenario 4) would produce a smaller total travel time, in the order of 7%, with a very positive impact on the bus speed of the selective lane section, 25%. Graph 1 presents the section total travel times.



Graph 1: Travel times (NETSIM)

3.3. Positive effects for a sustainable urban mobility

NETSIM shows values in fuel consumption for type of vehicle and for each link.

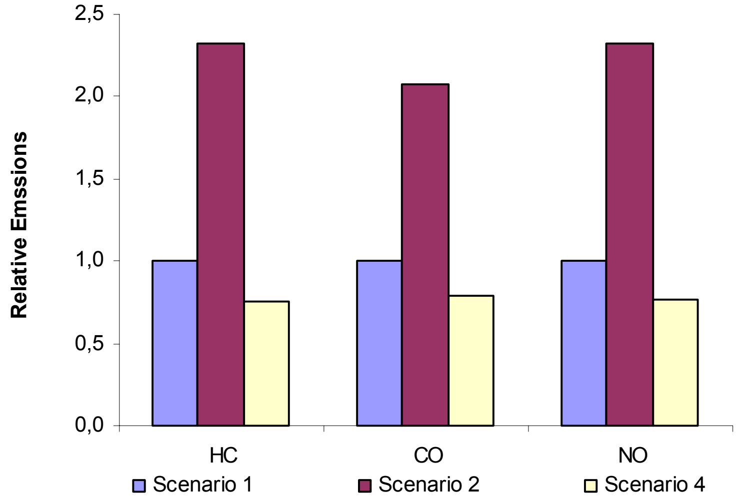
We considered the base case scenario to be the current situation, and on that basis, we obtained fuel consumption values for the different alternatives.

If there had been no modification with respect to the quantity and type of use given to the lanes assigned for public transport since 2000, then the increases in fuel consumption would have been of around 90% for passenger cars and 11% for mass public transport vehicles, given that the total volume of circulating vehicles would have decreased13% under that scenario (Scenario 2) and speed would have had a 44% decrease. In addition, passenger cars HC, CO, and NO pollutant emissions would have increased at around 150% in their values. This clearly shows the need to apply infrastructure and control measures all along, so as to ensure the efficient use of environmental and energy resources.

The benefits of having governmental policies favouring mass public transport in the current situation are the following: fuel consumption can decrease 19%, circulating volume can increase 12%, and speed can increase 25%.

Most benefits can most clearly be seen in the street blocks with selective lanes and with the highest number of bus stops for different bus lines.

If we were to prohibit turning right from selective lanes, in the current situation, then the benefits would be the following: fuel consumption in passenger cars, HC, CO y NO, would be around 20% less, and the savings in fuel for passenger cars would be of 15%, while those for buses would be of 2% only. Graph 2 below clearly shows these benefits.



Graph 2: Relative emissions with respect to current situation

Some important observations:

- It is clear that the artery would function with slower speeds than the current ones with no third selective lane.

- If we only had two selective lanes, and these lanes would exclusively be for mass public transport (buses, and trolley buses, no taxis or hire cars), then the results would have been slightly superior to the ones in the current situation (three selective lanes for public transport, including taxis and hire cars)

- If, in addition to the current policy, we prohibit individual public transport vehicles from turning right on selective lanes, then the circulation of buses would again be improved.

- The application of measures that benefit the circulation of mass transport vehicles entail a positive impact on the general well-being in environmental terms as well as in the use of energy resources.

4. CONCLUSIONS

There are tools, such as simulation models, which give good results when studying different management policies.

In this case, the NETSIM model proved to be the adequate one for the analysis of the phenomena.

Keeping in mind the goal of setting up a sustainable mobility, we believe that clear measures in favour of mass transport must be progressively applied. This implies a change of perspective, which is difficult but necessary if one wants to make the system efficiency optimal and ensure an economic use of resources.

The possibility of increasing the operation speed of the system in the downtown area, which is an area covered by almost all the transport lines, appears to be attractive since it allows a reduction of the total travel time.

That is the importance of making travel time optimal, since it provides benefits at different levels as listed below:

- to the users, since it allows them to decrease their total travel time
- to the transport operators, since it allows them to better adjust the size of their available fleet necessary to respond to the demand.
- to the environment, since there is a decrease in the emission of pollutants.

The results obtained in this study illustrate the importance of traffic integrated management policies which can make the circulation of mass public transport more efficient.

At the same time, these results highlight that it is not always the case that the best policy is the one that adds more selective lanes. In fact, we have shown that the circulation of mass public transport can be efficient when we adopt measures that aim at making mass public transport a priority by having bus only lanes and by forbidding passenger cars from turning right on selective lanes. This has allowed the speed of operation to increase in approximately 30%.

The before and after studies allowed the verification of hypothesized effects and also provide a basis for future research.

5. REFERENCES

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